6 WILCOXON RANK SUM TEST: CONTAMINANT PRESENT IN BACKGROUND

The statistical tests discussed in this section will be used to compare each survey unit with an appropriately chosen, site-specific reference area. Each reference area should be chosen on the basis of its similarity to the survey unit, as discussed in Section 2.2.7.

In Scenario A, the comparison of measurements from the reference area and survey unit is made using the Wilcoxon Rank Sum (WRS) test (also called the Mann-Whitney test).

Under Scenario B, the comparison of measurements in the reference area and survey unit is made using two nonparametric statistical tests: the WRS test and the Quantile test. The WRS and Quantile tests are both used because each test detects different residual contamination patterns in the survey units. Because two tests are used, the Type I error rate, α, specified during the DQO process is halved for the individual tests. The Quantile test is discussed in Chapter 7.

In addition to the statistical tests, the EMC is performed against each measurement to assure that it does not exceed a specified investigation level. If any measurement in the remediated survey unit exceeds the specified investigation level, then additional investigation is recommended, at least locally, regardless of the outcome of the WRS or Quantile test.

The WRS test is most effective when residual radioactivity is uniformly present throughout a survey unit. The test is designed to detect whether or not this activity exceeds the $DCGL_W$. The advantage of the nonparametric WRS test is that it does not assume that the data are normally or log-normally distributed. The WRS test also allows for less than detectable measurements in either the reference area or the survey unit. As a general rule, the WRS test can be used with up to 40% less than detectable measurements in the reference area and the survey unit combined. However, the use of less than values in data reporting is not encouraged. Wherever possible, the actual result of a measurement, together with its uncertainty, should be reported.

6.1 Introduction

The use of the WRS test in Scenario A and Scenario B are described in the next two sections, illustrated with example data. We consider a Class 2 survey consisting of interior drywall surfaces, that may have some residual radioactivity. The $DCGL_W$ for the radionuclide in question has been determined to be 160. (The particular radionuclide and units of measurement are irrelevant to the example, and will be left arbitrary.) The background level is about 40. It is estimated that the standard deviation of the measurements in the survey unit and the reference area is about 6.

Since the $DCGL_W$ is so much larger than σ, large sample sizes will not be needed even if the acceptable error rates are set to low values. In this circumstance, the rule of thumb that Δ/σ should lie between one and three can be used to set the Lower Bound of the Gray Region (LBGR). If, for example, $\Delta/\sigma = 3$, then $\Delta = 18$, since σ is estimated at 6. The Lower Bound of the Gray Region is then LBGR = $DCGL_W - \Delta = 160 - 18 = 142$. If the decision error rates are both set equal to 0.05 initially, then from Table 3.3, for $\alpha = \beta = 0.05$ with $\Delta/\sigma = 3$, ten samples each are required in the reference area and the survey unit.

Under Scenario B, the Type I error rate is halved, so $\alpha_W = \alpha/2 = 0.05/2 = 0.025$. Then, again from Table 3.3, for $\alpha = 0.025$, $\beta = 0.05$, and $\Delta/\sigma = 3$, twelve samples each are required in the reference area and the survey unit. The corresponding chart of the desired probability that the survey unit passes is shown in Figure 6.1. Note that, although the probability that a survey unit at the LBGR passes the WRS test in Scenario B is 97.5%, the overall probability of passing both the WRS and Quantile tests is approximately 95%.

Since both scenarios are illustrated using the same set of data, the larger sample size will be used for both.

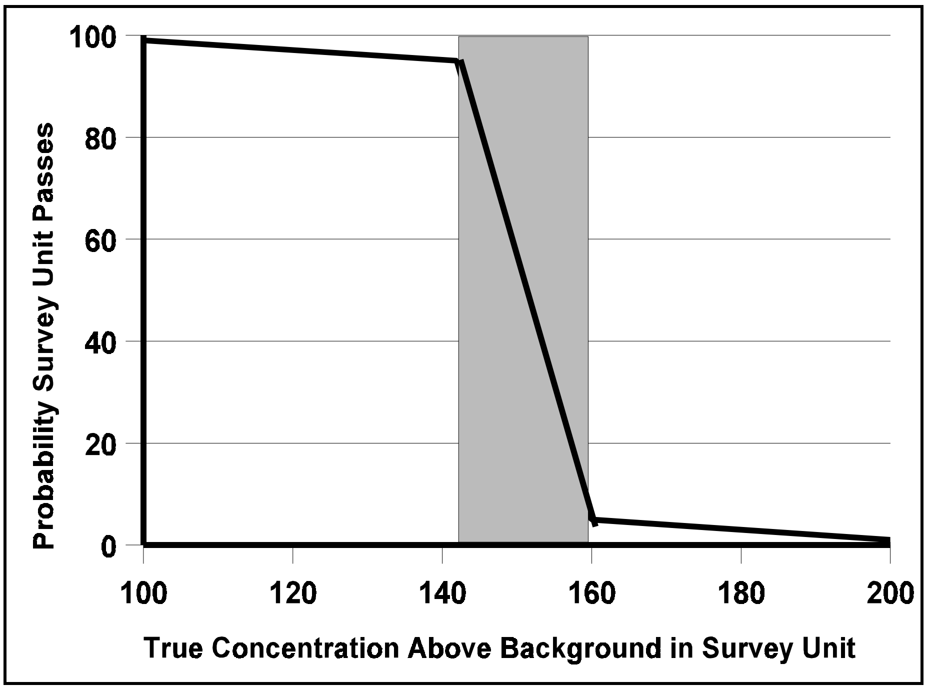

Figure 6.1 Desired Probability That the Survey Unit Passes

The data were taken on a triangular grid[1], and the posting plot is shown in Figure 6.2. For this example the concentration of the radionuclide of interest is given in arbitrary units. It is clear from this plot that there is residual radioactivity above background in the survey unit.

Summary statistics for these data are shown in Table 6.1. The mean and median are fairly close in both the reference area and the survey unit. The standard deviations of the data are slightly larger than estimated during the survey design, but the ratio Δ/σ remains above 2, so the impact on the power of the tests should not be severe. The range of the data is between 3 and 4 standard

[1] A random start systematic grid is used in Class 2 and 3 survey units primarily to limit the size of any potential elevated areas. Since areas of elevated activity are not an issue in the reference areas, the measurement locations can be either random or on a random start systematic grid.

deviations, which is about right for these sample sizes (see Figure 4.1).

Reference Area

	0 E	10 E	20 E
70 N		51	
60 N	35		39
50 N		32	
40 N	43		34
30 N		45	
20 N	37		39
10 N		36	
0 N	47		28

Survey Unit

	0 E	10 E	20 E	30 E
50 N		187		177
40 N	193		188	
30 N		188		180
20 N	193		187	
10 N		188		191
0 N	207		197	

Figure 6.2 Posting Plot of Reference Area and Survey Unit Data

Table 6.1 Summary Statistics for Example Data of Figure 6.2

Reference Area			Survey Unit	
Mean	38.8		Mean	189.8
Median	38		Median	188
Std Dev	6.6		Std Dev	8.1
Kurtosis	−0.4		Kurtosis	2.2
Skewness	0.3		Skewness	0.9
Range	23		Range	32
Minimum	28		Minimum	177
Maximum	51		Maximum	209
Count	12		Count	12

A histogram of the data is shown in Figure 6.3. The data distributions are fairly symmetric. The survey unit and reference area distributions are clearly separated by an amount much larger than the width of either. The difference in the medians is 188 − 38 = 150, and the difference in the means is 189.8 − 38.8 = 151. Both of these values are very close to the $DCGL_W$ of 160. It is in just such cases that the statistical tests are most useful in determining the significance of these values.

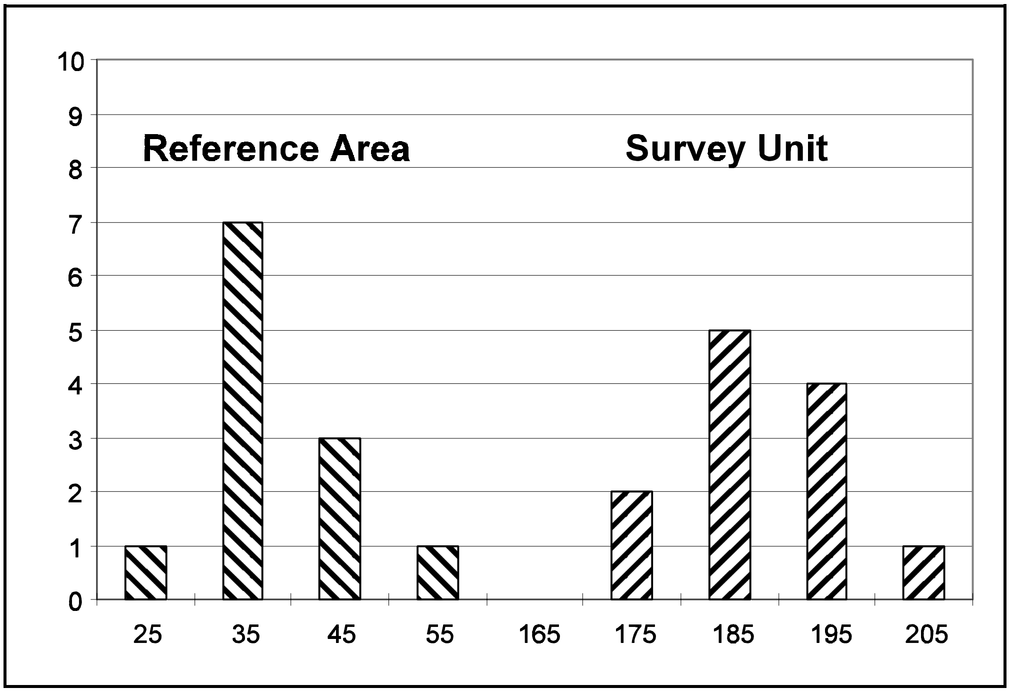

Figure 6.3 Histograms of Reference Area and Survey Unit Data

Since there are equal numbers of data in the reference area and in the survey unit, a Quantile-Quantile plot is easily constructed. Table 6.2 shows the reference area and survey unit data each separately ranked in increasing order. The pairs of data from the reference area and the survey unit with the same rank are plotted in Figure 6.4. This is the Quantile-Quantile plot. The position of the medians is indicated by the solid bar and the central 50% of the data is enclosed in the dashed box. The plot is fairly straight, and the slope is not greatly different from one, indicating the the shapes of the reference area and survey unit distributions are similar. However, the survey unit distribution is shifted to values about 150 larger. Again, the significance of this relative to the $DCGL_W$ is precisely what the WRS test is designed to determine.

Table 6.2 Ranked Data for Example of Figure 6.2

Rank	Reference Area		Rank	Survey Unit
1	28		1	177
2	32		2	180
3	34		3	187
4	35		4	187
5	36		5	188
6	37		6	188
7	39		7	188
8	39		8	191
9	43		9	193
10	45		10	193
11	47		11	197
12	51		12	207

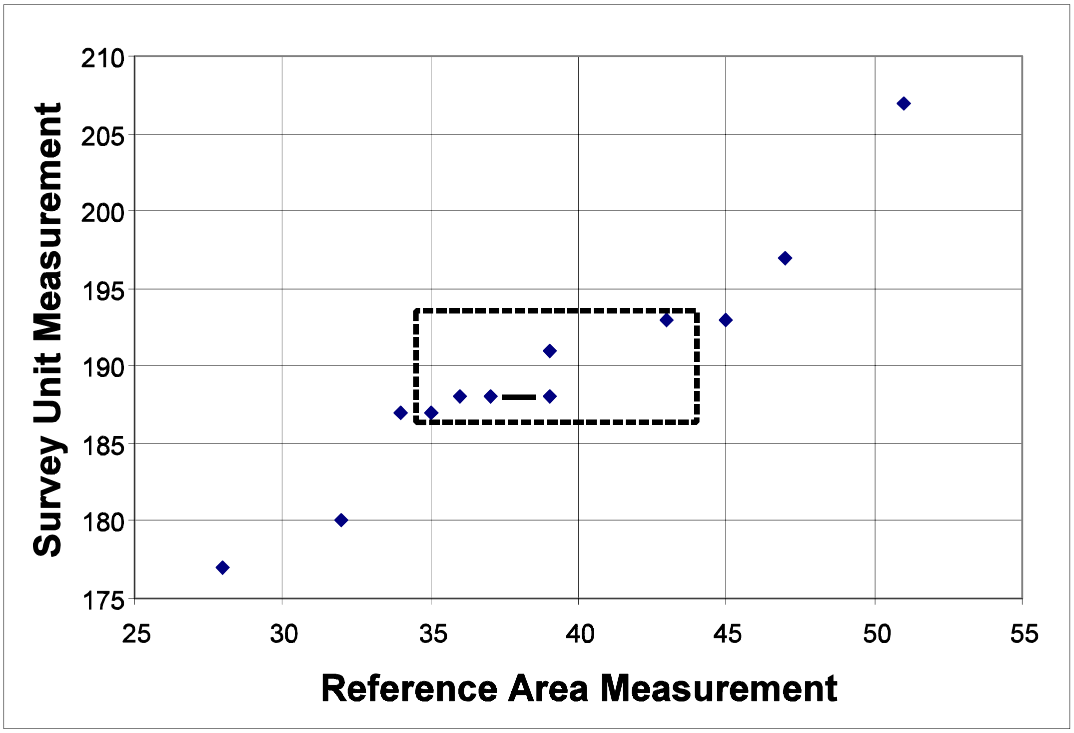

Figure 6.4 Quantile-Quantile Plot of Example Data

6.2 Applying the WRS Test: Scenario A

The hypothesis tested by the WRS test under Scenario A is:

Null Hypothesis:

H_0: The median concentration in the survey unit exceeds that in the reference area by more than the $DCGL_W$.

versus

Alternative Hypothesis:

H_a: The median concentration in the survey unit exceeds that in the reference area by less than the LBGR.

The null hypothesis is assumed to be true unless the statistical test indicates that it should be rejected in favor of the alternative. One assumes that any difference between the reference area and survey unit concentration distributions is due to a shift in the survey unit concentrations to higher values—i.e., due to the presence of residual radioactivity in addition to background. The size of this shift is the difference in the mean concentrations. The median is equal to the mean when the measurement distributions are symmetric, and is an approximation otherwise.
Note that some or all of the survey unit measurements may be larger than some reference area measurements, while still meeting the release criterion. Indeed, some survey unit measurements

may exceed some reference area measurements by more than the $DCGL_W$. The result of the hypothesis test determines whether or not the survey unit as a whole is deemed to meet the release criterion. The EMC is used to screen individual measurements.

Assumptions underlying this test are that (1) the samples from the reference area and the survey unit are independent random samples, and (2) each measurement is independent of every other measurement—regardless of the set of samples from which it came.

The hypothesis specifies a release criterion in terms of a $DCGL_W$ which is calculated as described in Section 3.3. The test should have sufficient power ($1-\beta$, as specified in the DQOs) to detect residual radioactivity concentrations at the Lower Boundary of the Gray Region (LBGR). If σ is the standard deviation of the measurements in the survey unit, then Δ/σ expresses the size of the shift (i.e. $\Delta = DCGL_W - LBGR$) as the number of standard deviations that would be considered large for the distribution of measurements in the survey unit. The procedure for determining Δ/σ was given in Section 3.8.1.

The WRS test is applied as follows under Scenario A:

(1) Obtain the adjusted reference area measurements, Z_i , by adding the $DCGL_W$ to each reference area measurement, X_i. $Z_i = X_i + DCGL_W$

(2) The m adjusted reference area sample measurements, Z_i, and the n survey unit sample measurements, Y_i , are pooled and ranked in order of increasing size from 1 to N, where $N = m+n$.

(3) If several measurements are tied (have the same value), they are all assigned the average rank of that group of tied measurements.

(4) If there are t less than detectable values, they are all assigned the rank $(t + 1)/2$. If there is more than one detection limit, all observations below the largest detection limit should be treated as less than detected. If more than 40% of the data from either the reference area or survey unit are less than detectable, the WRS test *cannot* be used. As stated previously, the use of less than values in data reporting is not encouraged. Wherever possible, the actual result of a measurement, together with its uncertainty, should be reported.

(5) Sum the ranks of the adjusted measurements from the reference area, W_r. Note that since the sum of the first N integers is $N(N+1)/2$, one can equivalently sum the ranks of the measurements from the survey unit, W_s, and compute $W_r = N(N + 1)/2 - W_s$.

(6) Compare W_r with the critical value given in Table A.4 for the appropriate values of n, m, and α. If W_r is greater than the tabulated value, reject the hypothesis that the survey unit exceeds the release criterion.

The data for the example are shown in column A of Table 6.3 In column B, the code *R* was inserted to denote a reference area measurement, and *S* to denote a survey unit measurement. In column A, the data are simply listed as they were obtained. Column C contains the adjusted data. The adjusted data are obtained by adding the $DCGL_W$ to the reference area measurements.

The ranks of the adjusted data appear in Column D. They range from 1 to 24, since there is a total of 12 + 12 measurements. The sum of all the ranks is $N(N + 1)/2 = (24)(25)/2 = 300$. Column E contains only the ranks belonging to the adjusted reference area measurements. The sum of the ranks of the adjusted reference area data is 199. From Table A.4, for $\alpha = \beta = 0.05$ and $n = m = 12$, we find that the critical value is 179. Thus, the sum of the reference area ranks, 199, is greater than the critical value, 179, and the null hypothesis that the survey unit concentrations exceed the $DCGL_W$ is rejected. In Scenario A, the survey unit passes.

The analysis for the WRS test is very well suited to the use of a computer spreadsheet. The spreadsheet formulas in Microsoft Excel™ (1993) used for the example above are given in Table 6.4.

Table 6.3 WRS Test for Class 2 Interior Drywall Survey Unit
(Measurements from the reference area and the survey unit are denoted by R and S, respectively)

	A	B	C	D	E
1	**Data**	**Area**	**Adjusted Data**	**Ranks**	**Reference Area Ranks**
2	47	R	207	22	22
3	28	R	188	6.5	6.5
4	36	R	196	15	15
5	37	R	197	16.5	16.5
6	39	R	199	18.5	18.5
7	45	R	205	21	21
8	43	R	203	20	20
9	34	R	194	13	13
10	32	R	192	10	10
11	35	R	195	14	14
12	39	R	199	18.5	18.5
13	51	R	211	24	24
14	209	S	209	23	—
15	197	S	197	16.5	—
16	188	S	188	6.5	—
17	191	S	191	9	—
18	193	S	193	11.5	—
19	187	S	187	3.5	—
20	188	S	188	6.5	—
21	180	S	180	2	—
22	193	S	193	11.5	—
23	188	S	188	6.5	—
24	187	S	187	3.5	—
25	177	S	177	1	—
26			**Sum =**	**300**	**199**

Table 6.4 Spreadsheet Formulas Used in Table 6.3

	A	B	C	D	E
1	**Data**	**Area**	**Adjusted Data**	**Ranks**	**Reference Ranks**
2	47	R	=IF(B2="R",A2+160,A2)	=RANK(C2,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C2) - 1) / 2	=IF(B2="R",D2,0)
3	28	R	=IF(B3="R",A3+160,A3)	=RANK(C3,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C3) - 1) / 2	=IF(B3="R",D3,0)
4	36	R	=IF(B4="R",A4+160,A4)	=RANK(C4,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C4) - 1) / 2	=IF(B4="R",D4,0)
5	37	R	=IF(B5="R",A5+160,A5)	=RANK(C5,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C5) - 1) / 2	=IF(B5="R",D5,0)
6	39	R	=IF(B6="R",A6+160,A6)	=RANK(C6,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C6) - 1) / 2	=IF(B6="R",D6,0)
7	45	R	=IF(B7="R",A7+160,A7)	=RANK(C7,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C7) - 1) / 2	=IF(B7="R",D7,0)
8	43	R	=IF(B8="R",A8+160,A8)	=RANK(C8,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C8) - 1) / 2	=IF(B8="R",D8,0)
9	34	R	=IF(B9="R",A9+160,A9)	=RANK(C9,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C9) - 1) / 2	=IF(B9="R",D9,0)
10	32	R	=IF(B10="R",A10+160,A10)	=RANK(C10,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C10) - 1) / 2	=IF(B10="R",D10,0)
11	35	R	=IF(B11="R",A11+160,A11)	=RANK(C11,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C11) - 1) / 2	=IF(B11="R",D11,0)
12	39	R	=IF(B12="R",A12+160,A12)	=RANK(C12,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C12) - 1) / 2	=IF(B12="R",D12,0)
13	51	R	=IF(B13="R",A13+160,A13)	=RANK(C13,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C13) - 1) / 2	=IF(B13="R",D13,0)
14	209	S	=IF(B14="R",A14+160,A14)	=RANK(C14,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C14) - 1) / 2	=IF(B14="R",D14,0)
15	197	S	=IF(B15="R",A15+160,A15)	=RANK(C15,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C15) - 1) / 2	=IF(B15="R",D15,0)
16	188	S	=IF(B16="R",A16+160,A16)	=RANK(C16,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C16) - 1) / 2	=IF(B16="R",D16,0)
17	191	S	=IF(B17="R",A17+160,A17)	=RANK(C17,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C17) - 1) / 2	=IF(B17="R",D17,0)
18	193	S	=IF(B18="R",A18+160,A18)	=RANK(C18,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C18) - 1) / 2	=IF(B18="R",D18,0)
19	187	S	=IF(B19="R",A19+160,A19)	=RANK(C19,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C19) - 1) / 2	=IF(B19="R",D19,0)
20	188	S	=IF(B20="R",A20+160,A20)	=RANK(C20,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C20) - 1) / 2	=IF(B20="R",D20,0)
21	180	S	=IF(B21="R",A21+160,A21)	=RANK(C21,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C21) - 1) / 2	=IF(B21="R",D21,0)
22	193	S	=IF(B22="R",A22+160,A22)	=RANK(C22,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C22) - 1) / 2	=IF(B22="R",D22,0)
23	188	S	=IF(B23="R",A23+160,A23)	=RANK(C23,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C23) - 1) / 2	=IF(B23="R",D23,0)
24	187	S	=IF(B24="R",A24+160,A24)	=RANK(C24,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C24) - 1) / 2	=IF(B24="R",D24,0)
25	177	S	=IF(B25="R",A25+160,A25)	=RANK(C25,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C25) - 1) / 2	=IF(B25="R",D25,0)
26			Sum =	299	=SUM(E2:E25)

Note that some spreadsheet programs assign the *lowest* rank in a group of ties to every member of the group, rather than the *average* rank for the group. This can be corrected by adding to each rank the value (g -1)/2, where g is the number of data points in the group. This is the function of the COUNTIF statement in column D of Table 6.4.

6.3 Applying the WRS Test: Scenario B

Two tests are used in Scenario B to ensure that there is adequate power to detect a survey unit that does not meet the release criterion. The concept of the statistical power of a test was discussed in Section 2.3.2. The WRS test has more power than the Quantile test to detect uniform failure of remedial action throughout the survey unit. The Quantile test has more power than the WRS test to detect failure of remedial action in only a few areas within the survey unit. These nonparametric tests do not require that the data be normally or log-normally distributed. Measurements reported as non-detects may also be used with these tests, although this practice is discouraged(2). As a general rule, the WRS test can be used with up to 40% less than detectable measurements in either the reference area or the survey unit. The Quantile test can be used even when more than 50% of the measurements are below the limit of detection.

In addition, an elevated measurement comparison is conducted. This consists of determining if any measurements in the remediated survey unit exceed a specified investigation level. If so, then additional investigation is required, at least locally, regardless of the outcome of the WRS and Quantile tests.

The hypothesis tested by the WRS test under Scenario B is:

Null Hypothesis:

$\mathbf{H_0}$: The difference in the median concentration of radioactivity in the survey unit and in the reference area is less than the LBGR.

versus

Alternative Hypothesis:

$\mathbf{H_a}$: The difference in the median concentration of radioactivity in the survey unit and in the reference area is greater than the $DCGL_W$.

The Type I error rate, $\alpha_W = \alpha/2$, is the probability that a survey unit with residual radioactivity (above background) at the LBGR will fail this test. The power, $1-\beta$, is the probability that a survey unit with residual radioactivity at the $DCGL_W$ will fail this test.

The WRS test is applied as follows under Scenario B:

(1) Obtain the adjusted survey unit measurements, Z_i , by subtracting the LBGR from each

(2) All actual measurement results (with an associated uncertainty) should be reported, even if they are negative, so that unbiased estimates of averages can be calculated.

survey unit measurement, Y_i. $Z_i = Y_i - LBGR$

(2) The n adjusted survey unit measurements, Z_i , and the m reference area measurements, X_i , are pooled and ranked in order of increasing size from 1 to N, where $N = m+n$.

(3) If several measurements are tied (have the same value), they are all assigned the average rank of that group of tied measurements.

(4) If there are t less than detectable values, they are all assigned the rank $(t + 1)/2$. If there is more than one detection limit, all observations below the largest detection limit should be treated as less than detectable. If more than 40% of the data from either the reference area or survey unit are less than detectable, the WRS test *cannot* be used.

(5) Sum the ranks of the adjusted measurements from the survey unit, W_s. Note that since the sum of the first N integers is $N(N + 1)/2$, one can equivalently sum the ranks of the measurements from the reference area, W_r , and compute $W_s = N(N + 1)/2 - W_r$.

(6) Compare W_s with the critical value given in Table A.4 for the appropriate values of n, m, and α. If W_s is greater than the tabulated value, reject the hypothesis that the difference in the median concentration between the survey unit and the reference area is less than the LBGR.

The data for the example are shown in column A of Table 6.5 In column B, the code *R* was inserted to denote a reference area measurement, and *S* to denote a survey unit measurement. In column A, the data are simply listed as they were obtained. Column C contains the adjusted data. The adjusted data are obtained by subtracting the LBGR from the survey unit measurements.

The ranks of the adjusted data appear in Column D. They range from 1 to 24, since there is a total of 12 + 12 measurements. The sum of all the ranks is $N(N + 1)/2 = (24)(25)/2 = 300$. Column E contains only the ranks belonging to the adjusted survey unit measurements. The sum of the ranks of the adjusted survey unit data is 194.5. From Table A.4, for $\alpha_W = \alpha/2 = 0.025$, $\beta = 0.05$, and $n = m = 12$, we find that the critical value is 184. Thus, the sum of the adjusted survey unit ranks, 194.5, is greater than the critical value, 184, and the null hypothesis that the survey unit concentrations do not exceed LBGR is rejected. In Scenario B, the true survey unit residual radioactivity is judged to be in excess of 142 above background.

The analysis for the WRS test is very well suited to the use of a computer spreadsheet. The spreadsheet formulas in Microsoft Excel™ (1993) used for the example above are given in Table 6.6. Note that some spreadsheet programs assign the *lowest* rank in a group of ties to every member of the group, rather than the *average* rank for the group. This can be corrected by adding to each rank the value $(g - 1)/2$, where g is the number of data points in the group. This is the function of the COUNTIF statement in column D of Table 6.6.

Table 6.5 WRS Test Under Scenario B for Class 2 Interior Drywall Survey Unit
(Measurements from the reference area and the survey unit are denoted by R and S, respectively)

	A	B	C	D	E
1	**Data**	**Area**	**Adjusted Data**	**Ranks**	**Survey Unit Ranks**
2	47	R	47	18	—
3	28	R	28	1	—
4	36	R	36	6	—
5	37	R	37	7	—
6	39	R	39	9.5	—
7	45	R	45	13	—
8	43	R	43	11	—
9	34	R	34	3	—
10	32	R	32	2	—
11	35	R	35	4.5	—
12	39	R	39	9.5	—
13	51	R	51	21	—
14	209	S	67	24	24
15	197	S	55	23	23
16	188	S	46	16	16
17	191	S	49	19	19
18	193	S	51	21	21
19	187	S	45	13	13
20	188	S	46	16	16
21	180	S	38	8	8
22	193	S	51	21	21
23	188	S	46	16	16
24	187	S	45	13	13
25	177	S	35	4.5	4.5
26			**Sum =**	**300**	**194.5**

Table 6.6 Spreadsheet Formulas Used in Table 6.5

	A	B	C	D	E
1	**Data**	**Area**	**Adjusted Data**	**Ranks**	**Survey Unit Ranks**
2	47	R	=IF(B2="S",A2-142,A2)	=RANK(C2,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C2) - 1) / 2	=IF(B2="S",D2,0)
3	28	R	=IF(B3="S",A3-142,A3)	=RANK(C3,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C3) - 1) / 2	=IF(B3="S",D3,0)
4	36	R	=IF(B4="S",A4-142,A4)	=RANK(C4,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C4) - 1) / 2	=IF(B4="S",D4,0)
5	37	R	=IF(B5="S",A5-142,A5)	=RANK(C5,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C5) - 1) / 2	=IF(B5="S",D5,0)
6	39	R	=IF(B6="S",A6-142,A6)	=RANK(C6,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C6) - 1) / 2	=IF(B6="S",D6,0)
7	45	R	=IF(B7="S",A7-142,A7)	=RANK(C7,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C7) - 1) / 2	=IF(B7="S",D7,0)
8	43	R	=IF(B8="S",A8-142,A8)	=RANK(C8,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C8) - 1) / 2	=IF(B8="S",D8,0)
9	34	R	=IF(B9="S",A9-142,A9)	=RANK(C9,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C9) - 1) / 2	=IF(B9="S",D9,0)
10	32	R	=IF(B10="S",A10-142,A10)	=RANK(C10,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C10) - 1) / 2	=IF(B10="S",D10,0)
11	35	R	=IF(B11="S",A11-142,A11)	=RANK(C11,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C11) - 1) / 2	=IF(B11="S",D11,0)
12	39	R	=IF(B12="S",A12-142,A12)	=RANK(C12,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C12) - 1) / 2	=IF(B12="S",D12,0)
13	51	R	=IF(B13="S",A13-142,A13)	=RANK(C13,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C13) - 1) / 2	=IF(B13="S",D13,0)
14	209	S	=IF(B14="S",A14-142,A14)	=RANK(C14,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C14) - 1) / 2	=IF(B14="S",D14,0)
15	197	S	=IF(B15="S",A15-142,A15)	=RANK(C15,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C15) - 1) / 2	=IF(B15="S",D15,0)
16	188	S	=IF(B16="S",A16-142,A16)	=RANK(C16,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C16) - 1) / 2	=IF(B16="S",D16,0)
17	191	S	=IF(B17="S",A17-142,A17)	=RANK(C17,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C17) - 1) / 2	=IF(B17="S",D17,0)
18	193	S	=IF(B18="S",A18-142,A18)	=RANK(C18,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C18) - 1) / 2	=IF(B18="S",D18,0)
19	187	S	=IF(B19="S",A19-142,A19)	=RANK(C19,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C19) - 1) / 2	=IF(B19="S",D19,0)
20	188	S	=IF(B20="S",A20-142,A20)	=RANK(C20,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C20) - 1) / 2	=IF(B20="S",D20,0)
21	180	S	=IF(B21="S",A21-142,A21)	=RANK(C21,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C21) - 1) / 2	=IF(B21="S",D21,0)
22	193	S	=IF(B22="S",A22-142,A22)	=RANK(C22,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C22) - 1) / 2	=IF(B22="S",D22,0)
23	188	S	=IF(B23="S",A23-142,A23)	=RANK(C23,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C23) - 1) / 2	=IF(B23="S",D23,0)
24	187	S	=IF(B24="S",A24-142,A24)	=RANK(C24,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C24) - 1) / 2	=IF(B24="S",D24,0)
25	177	S	=IF(B25="S",A25-142,A25)	=RANK(C25,$C$2:$C$25,1) +(COUNTIF($C$2:$C$25,C25) - 1) / 2	=IF(B25="S",D25,0)
26			Sum =	299	=SUM(E2:E25)

6.4 Interpretation of Test Results

Once the results of the statistical tests are obtained, the specific steps required to achieve site release will depend on the procedures described in the regulatory guide. The following are suggested considerations for the interpretation of the test results with respect to the release limit established for the site.

6.4.1 If the Null Hypothesis Is Not Rejected

Whenever the null hypothesis is not rejected, it is important to complete the analysis by performing a retrospective power analysis for the test. In Scenario A, this will ensure that further remediation is not required simply because the final status survey was not sensitive enough to detect the difference in mean radioactivity concentration between the survey unit and the reference area when that difference is below the LBGR. In Scenario B, this will ensure that a survey unit is not released simply because the final status survey was not sensitive enough to detect the difference in mean radioactivity concentration between the survey unit and the reference area when that difference is above the guideline level. The power analysis may be performed as indicated in Chapter 10, using the actual values of the number of measurements, N, and their observed measurement standard deviation *s* in place of σ. In some cases, a site-specific simulation of the retrospective power may be warranted when sufficient power cannot be demonstrated by any of the other suggested methods.

If the null hypothesis for the WRS test is not rejected in Scenario B, the Quantile test described in Chapter 7 must also be performed.

6.4.2 If the Null Hypothesis Is Rejected

If the null hypothesis for the Sign test is rejected in Scenario A, it indicates that the residual radioactivity in the survey unit is less than the $DCGL_W$. However, it may still be necessary to document the concentration of residual radioactivity. It is generally best to use the difference in mean radioactivity concentration between the survey unit and the reference area for this purpose.

If the null hypothesis is rejected in Scenario B, it indicates that the residual radioactivity in the survey unit exceeds the LBGR. In this case it is important to determine not only the difference in mean radioactivity concentration between the survey unit and the reference area, δ, but also whether this difference exceeds the release criteria. When the data are normally distributed, the average concentration is generally the best estimator for δ. However, when the data are not normally distributed, other estimators are often better for the same reasons that nonparametric tests are often better than the corresponding parametric tests. These methods are discussed by Lehmann and D'Abrera (1975) . When the estimate for δ is below $DCGL_W$, the survey unit may be judged sufficiently remediated, subject to ALARA considerations. Otherwise, further remediation will generally be required.